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INTEGRATED WELDING CONTROLS

WIRE FEED -- TRAVEL SPEED

by

Fred M. Freis

June 1, 1963

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ARMOUR RESEARCH FOUNDATION
of
ILLINOIS INSTITUTE OF TECHNOLOGY
Technology Center
Chicago 16, Illinois

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INTEGRATED WELDING CONTROLS:

WIRE FEED - TRAVEL SPEED

(2) [Final Report] (~~Covering the period~~ June 1962 ~~to~~ April 1963)

by

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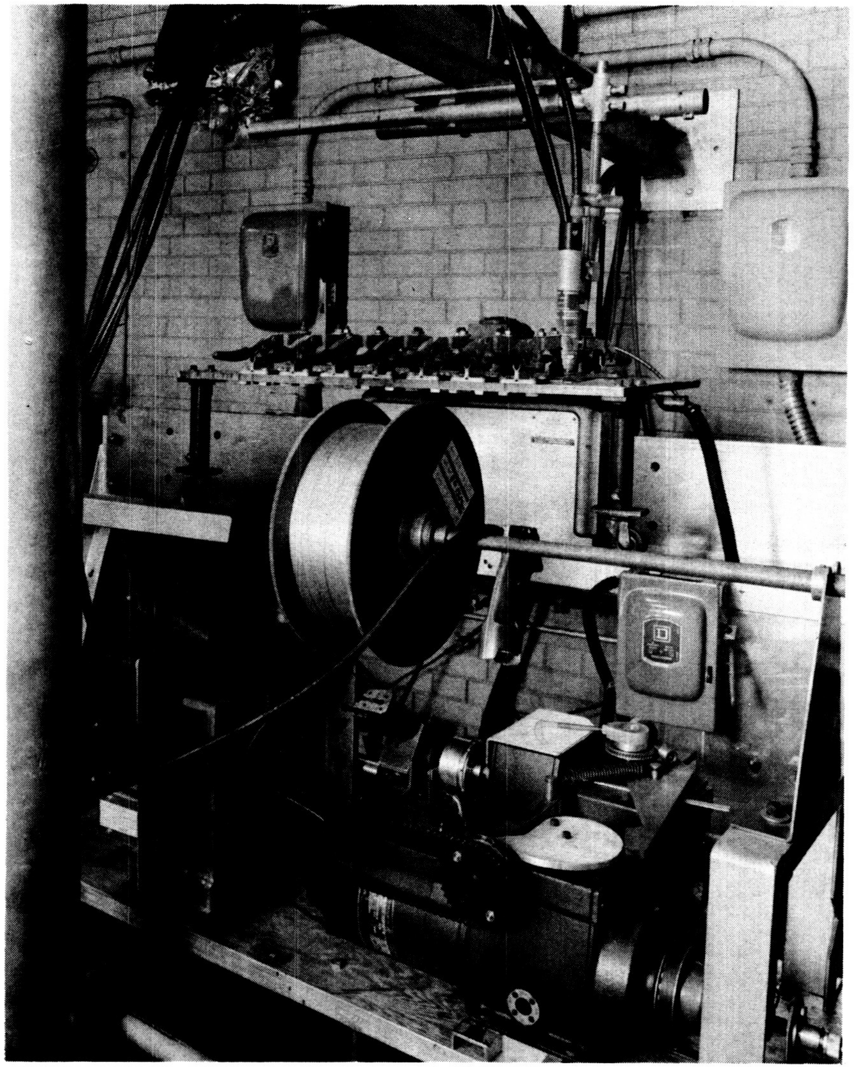

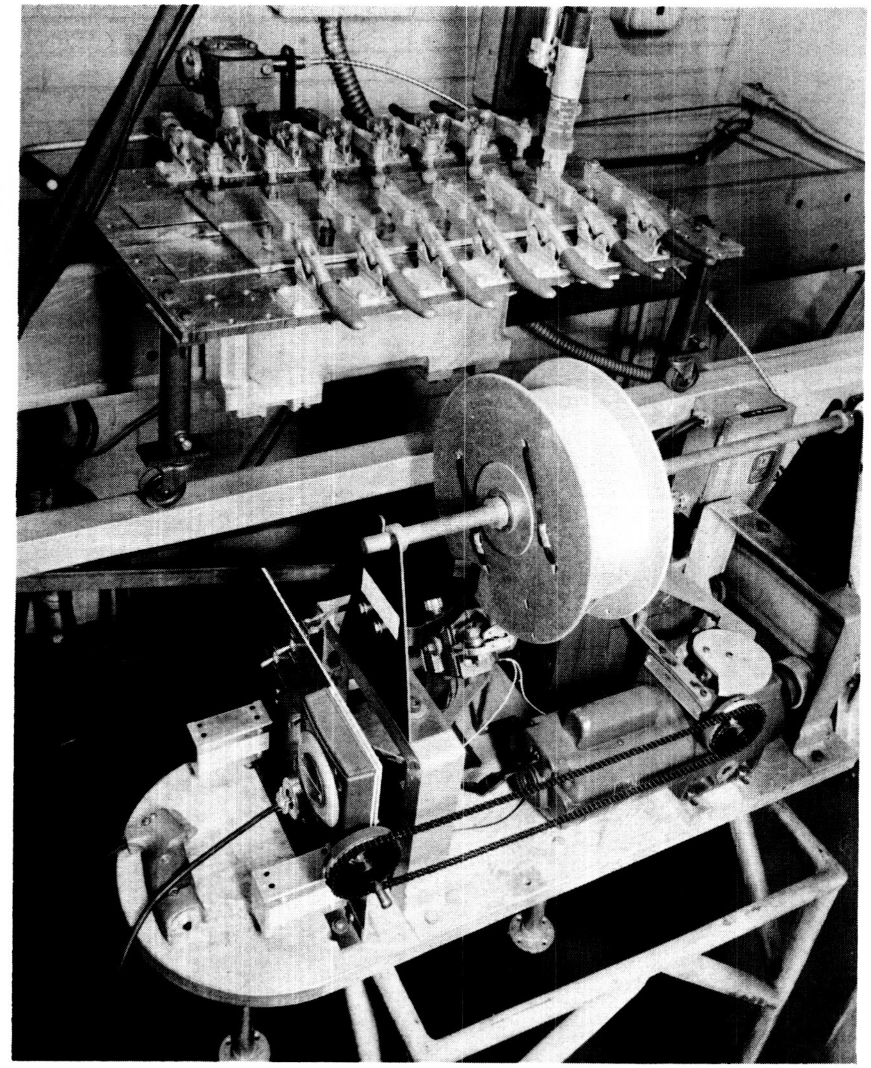

Frontispiece Complete Setup, Integrated Travel Speed-Wire Feed System

FOREWORD

This is the final report on Armour Research Foundation Project K267 "Integrated Welding Controls: Wire Feed - Travel Speed" conducted for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration under Contract NAS8-2667. Work on the program started June 1, 1962: The prototype of the system was complete and operational on April 5, 1963.

The objective of the program was to develop an optimum system of welding controls to integrate travel speed and wire feed in the MIG welding process without monitoring both variables independently. This system must control one variable by hand adjustment. Any variation in that parameter must result in automatic positive non-feedback adjustment of the other variable to conform to some predetermined relationship. This relationship must automatically compensate for the nonlinearily of the variables in the MIG process.

Foundation personnel who have contributed to this program are J. M. Ferez, F. M. Freis (Project Engineer), J. F. Rudy and E. H. Scharres. Mr. William A. Wilson and Mr. William M. Campbell of the Methods Research and Development Branch, Manufacturing Engineering Division, monitored the contract for NASA.

Respectfully submitted,

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ABSTRACT

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The report describes the development of an optimum system of welding controls to integrate travel speed and wire feed in the MIG welding process without monitoring both variables independently. The system must control one variable by hand adjustment. The prototype system is described and shown schematically.
Author

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I. INTRODUCTION

The Metal Inert Gas welding process, also designated MIG, is essentially an electric arc welding process in an atmosphere of an inert gas such as helium or argon. For a continuous welding system, the welding electrode is in wire form supplied from a large spool. It is fed mechanically through the welding torch at a predetermined rate. The welding torch, with the wire, moves along the weldment direction and is carried by a mechanically driven box. This unit is supported by a stationary beam. In this manner, two basic variables, the rate of wire feed and the rate of travel speed are accommodated.

Commercially available equipment for the continuous MIG welding process is usually furnished in two separate sections; one a portable box which contains the wire feed drive and wire supply, the other that part of the travel mechanism which rides on the stationary side beam and carries the torch. Each section has its own series motor and speed controls. In normal use, there are no mechanical or electronic interconnections between these two sections.

To produce a satisfactory weld, the operator of such a commercial equipment must find the correct control setting for the wire feed and travel speed by trial and error. However, the established control settings apply only for one chosen travel speed and one particular welding geometry in single pass welding.

It is known that the travel speed and wire speed should not be increased in direct proportion to fulfill the requirements of a volumetric weld deposit. Less heat is lost to the base metal as welding speeds increase, and less wire is needed. Therefore, a nonlinear interconnection between the travel speed and wire feed controls provides automatic compensation.

The objective of this project was to develop and build an integrated package including the travel drive and wire drive using positive non-feedback integrating controls.

II. PARAMETERS

The rate of heat input to a weld is given approximately by

$$H = \frac{VI}{S}$$

where

H = the heat, Joules/inch weld,

V = the arc voltage,

I = the arc current,

S = the travel speed, in/sec.

For a given weld-bead geometry, the heat input can be adjusted to melt a sufficient amount of welding wire at a predetermined travel speed. The amount of welding wire which can be melted by the adjusted heat H (in Btu) is found as follows:

$$H = M(C_p \Delta t + Q_f)$$

where

$\Delta = t = t_m - t_r$

M = mass of wire (volume x density)

C_p = specific heat

t_m = melting temp

t_r = room temp

Q_f = heat of fusion, Btu

from this,

$$M = \frac{H}{C_p \Delta t + Q_f}$$

and

$$\text{Volume} = \frac{M}{\text{density}} .$$

For a chosen wire diameter, the length of wire per second can be calculated from the volume. However, a considerable amount of heat loss occurs. This amount of heat loss is a variable and depends on the heat transfer properties of the mass of material to be welded, and also upon the travel speed.

To establish useful parameters of travel speeds and wire feed for a system, it is adequate to use simple volumetric calculations for the wire speeds for a given weld bead geometry and travel speed. For instance, for 90 deg, a V weld using 1/8-in. thick plates with a 0.040 in. thick butted section (i.e., the V is 0.085 deep) and assuming 1/16 in. diam welding wire, about 2-1/2 in. of filler wire are required per inch of weldment, or a speed ration of 2-1/2. Heavier weld bead geometrics can vary this ratio up to approximately 20 to 1.

III. THE PHOTOTYPE SYSTEM

Figure 1 shows a schematic of the drives. Speed transmission unit V-1 is driven by a 1/4-hp motor at constant speed at all times. The output of unit V-1 may be varied from zero to 1750 rpm. This unit drives the carriage assembly through an electric clutch and a flexible shaft. At 1750-rpm output using 3:1 change gears in the carriage, travel speeds of 40 in./min can be obtained. Higher travel speeds for multi-pass welding can be obtained by using change gear in a ratio of 2:1 or 1:1 as desired.

Unit V-1 also drives a second speed transmission unit V-2 through a timing belt and pulleys using a 1:1 ratio. The output speed of this unit can be varied using a speed change lever. A reducing gear box with a fixed ratio is attached to this unit. The resulting over-all ratio between the input and output shafts is 4.8:1. By varying the position of the speed lever, output speeds can be obtained in the range from zero to 1750/4.87 or 359 rpm. When one inch diameter pull rollers are used to drive the welding wire, wire speeds up to 1100 in. per min may be obtained.

By varying the output speed of transmission unit V-1, the travel speed will change. Transmission unit V-2 for the wire feed, will also change in a fixed ratio providing its speed lever remains fixed in one position. In practice however, it has been found that the ratio of travel speed and wire feed is not a linear function through a useful rnage of travel speeds. Less wire feed is required as the travel speeds increase. Therefore, the speed lever of transmission unit V-2 cannot remain fixed during changes in travel speed. A conversion table is included (Table 1) for convenience in finding travel speeds as a function of dial setting.

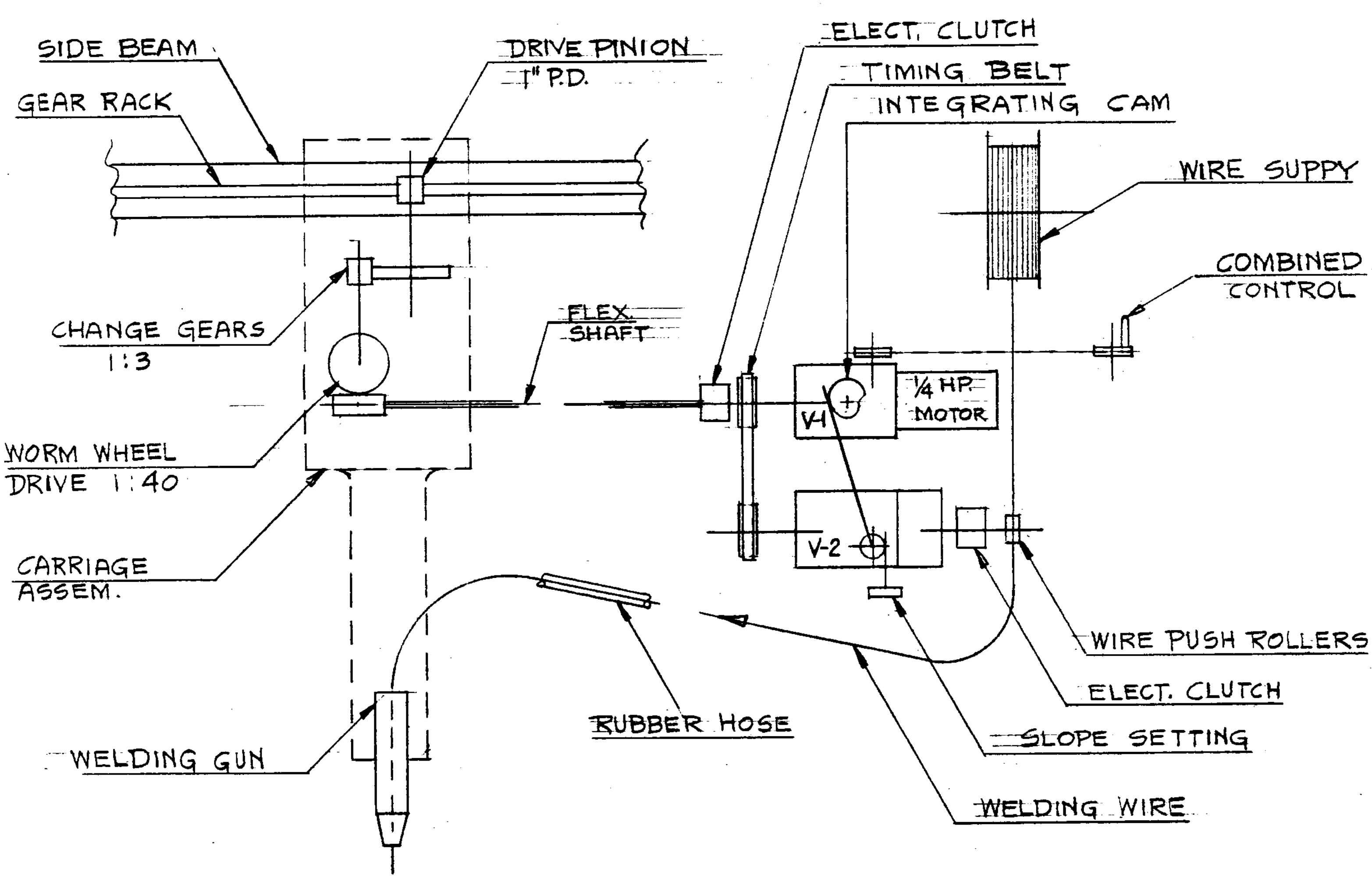
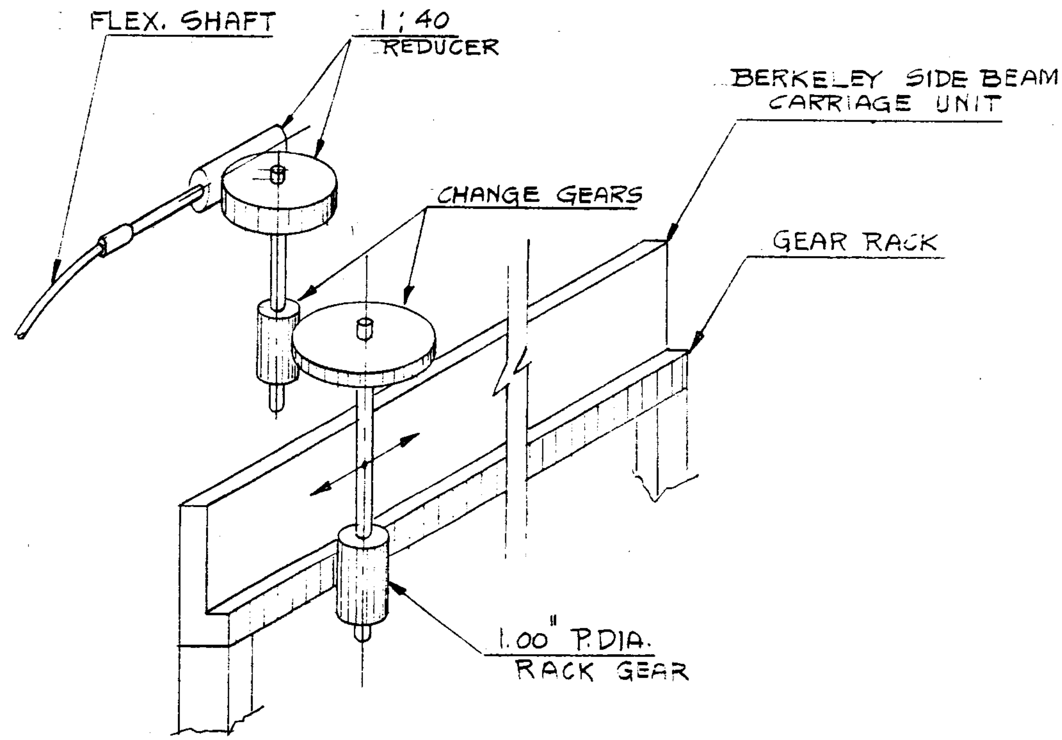


Fig. 1 Schematic of Drives Integrated Travel-Speed Wire Feed

DIAL SETTING	RPM OUTPUT FLEX. SHAFT	TRAVEL INCH. PER MIN. RATIO 1:3	RATIO 1:2	RATIO 1:1
1	35	.91	1.37	2.74
2	78	2.04	3.06	6.12
3	125	3.27	4.90	9.81
4	172	4.50	6.75	13.50
5	219	5.73	8.60	17.20
6	264	6.91	10.36	20.73
7	312	8.61	12.25	24.50
8	360	9.42	14.13	28.27
9	412	10.78	16.17	32.35
10	462	12.09	18.14	36.28
11	509	13.32	19.98	39.97
12	567	14.84	22.26	44.53
13	612	16.02	24.03	48.06
14	668	17.48	26.23	52.46
15	725	18.98	28.47	56.94
16	772	20.21	30.31	60.63
17	843	22.06	33.10	66.20
18	892	23.35	35.02	70.05
19	936	24.50	36.75	73.75
20	1010	26.44	39.66	79.32
21	1058	27.69	41.54	83.09
22	1113	29.13	43.70	87.41
23	1170	30.63	45.94	91.89
24	1230	32.20	48.30	96.60
25	1272	33.30	49.95	99.90
26	1337	35.00	52.50	105.00
27	1374	35.97	53.95	107.91
28	1446	37.85	56.72	135.68
29	1502	39.32	58.98	117.96
30	1539	40.29	60.43	120.87
31	1606	42.04	63.06	126.13
32	1652	43.24	64.87	129.74
33	1697	44.42	66.44	133.28
33¾	1736	45.44	68.17	136.34



CHANGE GEARS

RATIO	REDUCER GEAR	DRIVE SHAFT GEAR	RACK GEAR
1:1	24T	24T	12T
1:2	16T	32T	12T
1:3	12T	36T	12T

Table 1

CONVERSION TABLE

IV. TRAVEL SPEED - WIRE FEED INTEGRATION

To achieve automatically a continuous change of rate of the wire feed as the travel speeds increase, a mechanical inter-connection between the two drives is required. This interconnection must be positive non-feedback and must contain a memory according to a predetermined pattern. This is provided for in the form of a cam and cam-lever as shown in Fig. 2. The Graham speed transmission unit V-2 is furnished with a speed lever shaft as standard equipment. Attached to this shaft is the cam lever which reaches over to the speed transmission unit V-2 and contacts the cam. The cam is attached to the rotary speed control of the Graham transmission which is included as standard equipment.

As the rotary speed control of unit V-1 is being turned through a microdrive, the travel speed changes. This control also turns the cam and its rise or fall will move the cam lever attached to the shaft of the built-in speed lever of unit V-2.

It is necessary to know a reference point for a particular weldment geometry. For instance, it is known that such a reference point would be 275 in. of 1/16 in. diam wire at 20 inches travel per minute for a weldment geometry of 90 degree included angle v for 1/4-in. thick aluminum plate. The travel speed is simply set for 20 in. travel on the master dial. The wire speed must be adjusted for 275 in. per min. This is done by turning the thumb screw mounted on the cam lever, which brings the built-in speed lever into its proper position. This does not affect the cam lever. The proper position is indicated when the hand of the indicator coincides with the mark 1/4. For convenience, there are marks on the cam lever and the cam itself. When these marks line up, the slope adjustment is set at the 1/4 reading. These settings will then coincide with the previously established reference point. Wire speed integration is accomplished automatically in a similar manner by means of the cam for all other chosen travel speeds.

V. GENERATION OF CURVE TO INTEGRATE TORCH TRAVEL SPEED WITH WIRE FEED RATE

Torch travel speed ranged from 25 to 45 in. per min, and wire feed rate from 250 to 400 in. per min. Torch travel speed was held constant

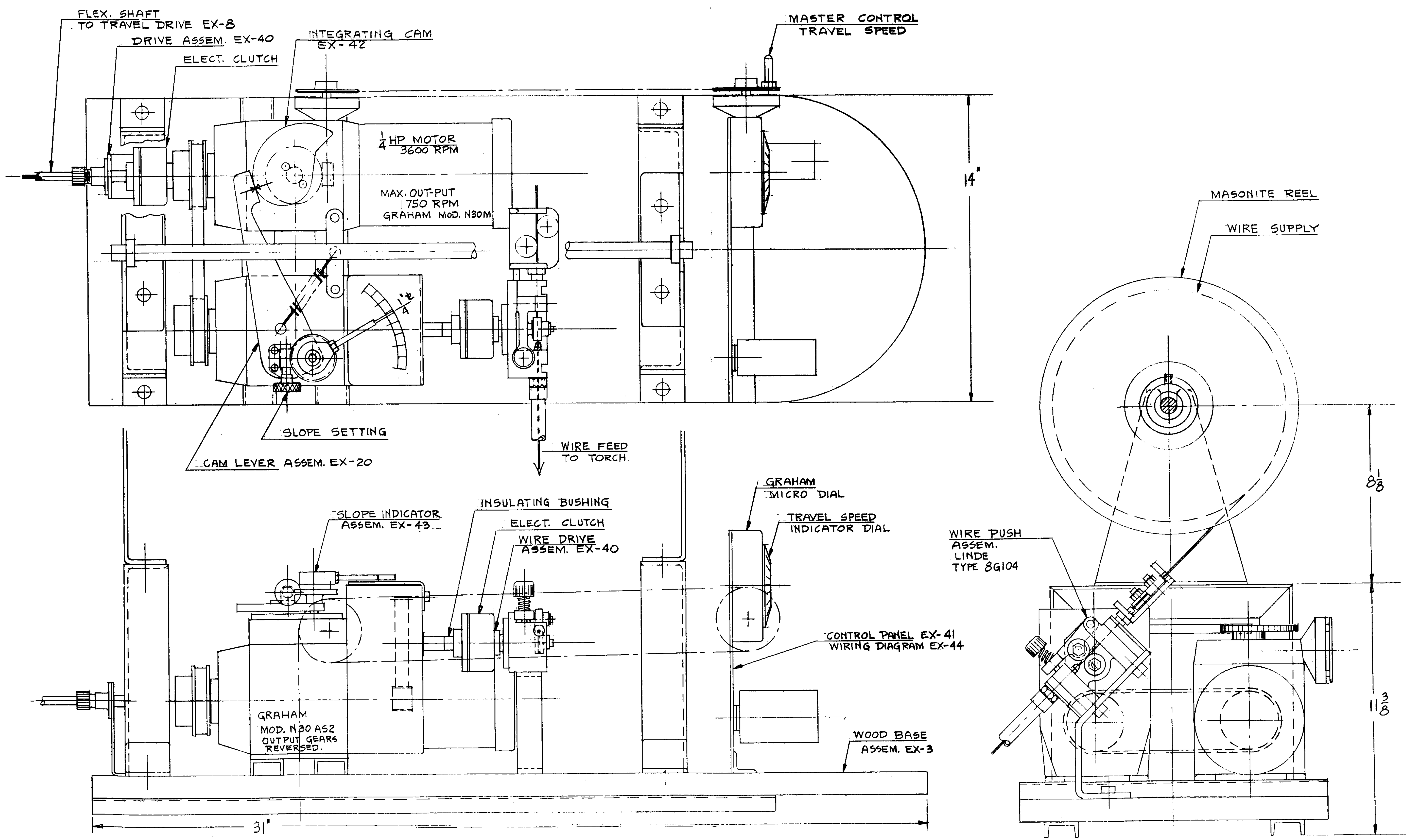


Fig. 2 Drive System Integrated Welding Controls Wire Feed-Travel Speed

for each test, and wire feed rate varied from one extreme to the other. Weldments were examined by cross sectioning to determine optimum wire feed; the proper wire feed was determined on the basis of the appearance of the weld cross section. This experiment was operated for torch travel speeds varying in increments of five in. per min from 25 to 45 in. per min. A series of experiments varying the wire speed, but holding the torch speed constant for a chosen value was conducted. Acceptable weldments were selected by visual inspection. Their corresponding wire speeds were then plotted on a graph (Fig. 3) with coordinates of wire speed versus travel speed. The complete series of experiments produces an array of points for the entire range of torch travel speeds concerned with in this program. A continuous curve representing the average value through the plotted points was drawn.

Cross sections of acceptable welds were made. Sections were etched and photographed. Welding variables pertinent to each selected weld joint plotted on graph Fig. 3 are tabulated on Table 2 with their corresponding cross sectional weldment pictures (Fig. 4). This integration curve was plotted for travel speeds from 20 in. per min to 40 in. per min. By setting the travel speed for 20 in. per min on the master control, the point of contact between cam and cam lever is found. To reach 40 in. per min, an additional 136 deg rotation on the speed control is required. Therefore, the cam must be designed in this region to decrease the wire speed in accordance with the curve, Fig. 3.

VI. OPERATING CONTROLS

At the start of the welding operation it is important that both the travel and wire movement go into action immediately. If the wire feed should start ahead of the travel movement, a flash-out which welds the wire to the end of the contact tube occurs. The travel drive represents a considerable inertia, whereas the wire drive has much less inertia. For this reason, a time delay for the wire drive has been incorporated in the circuitry of the controls.

A master switch turns on the 1/4-hp motor which brings both speed transmissions up to speed but will not drive the wire or carriage unless the electric clutches are actuated. Inching switches are provided in the circuitry

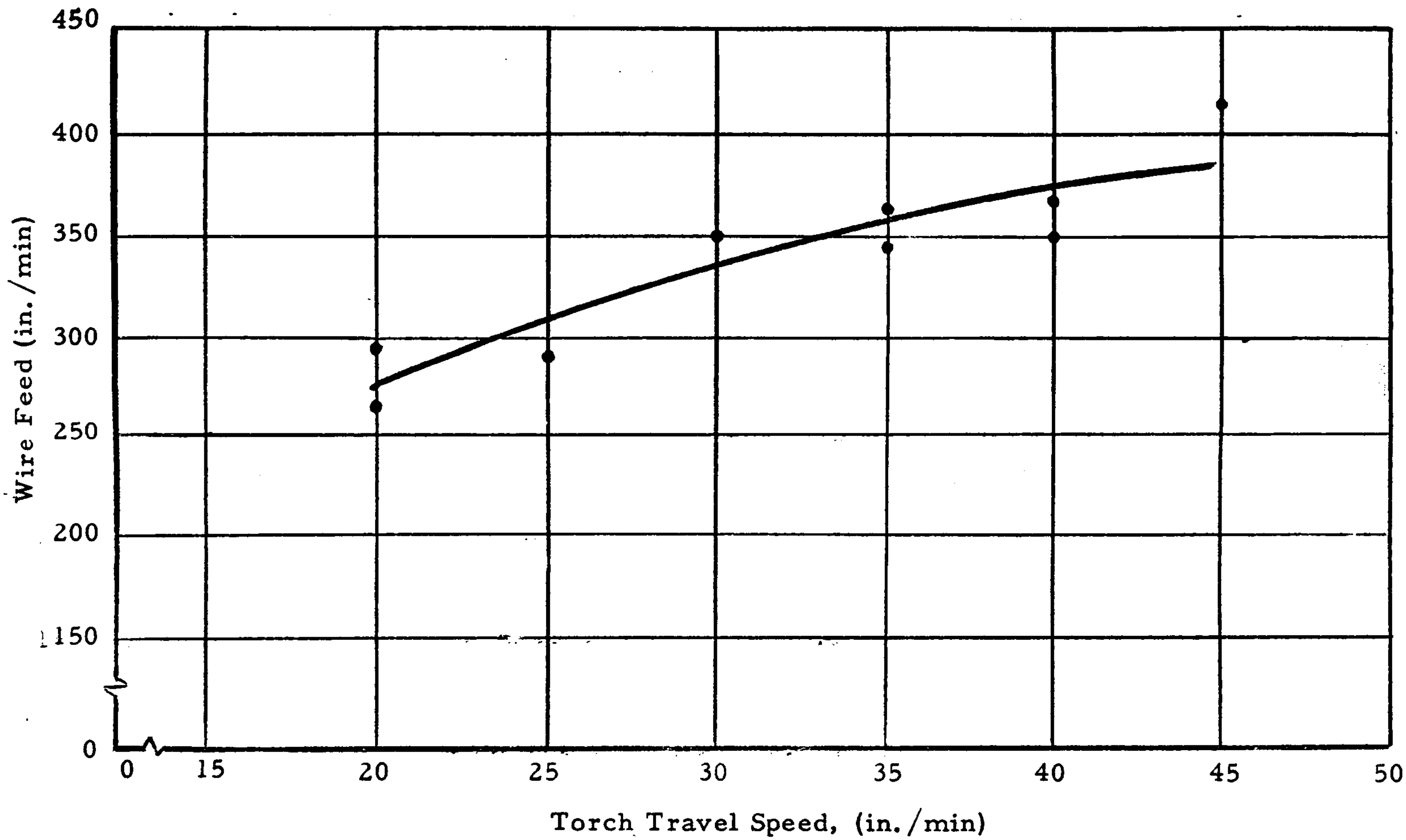
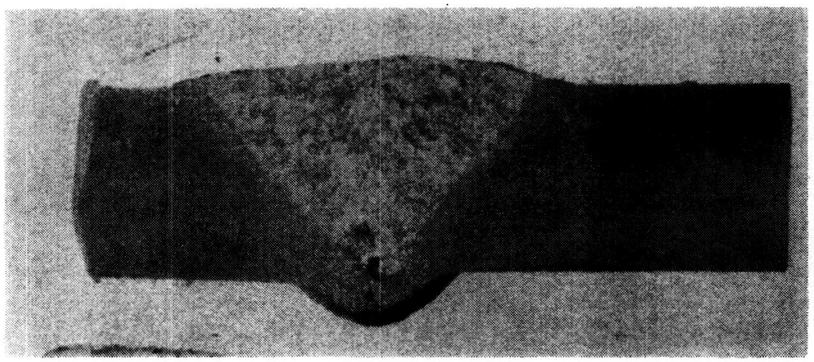


Fig. 3 Curve of Wire and Travel Speeds for Consistent Weldment Geometry



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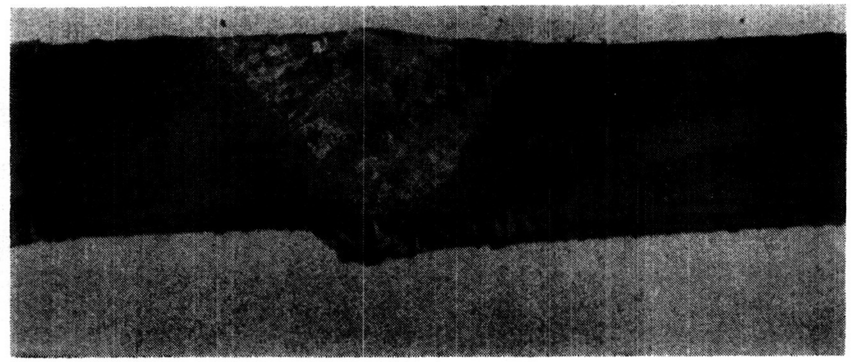

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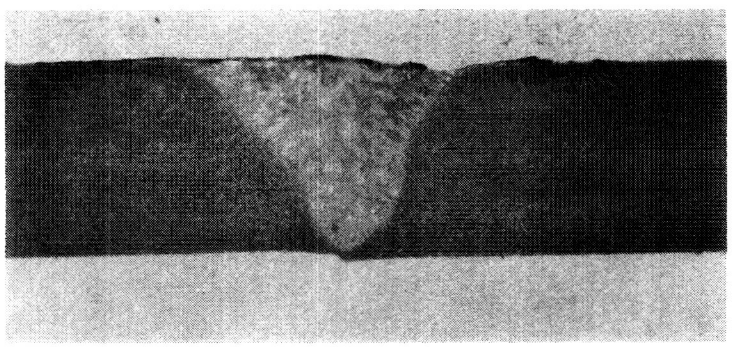

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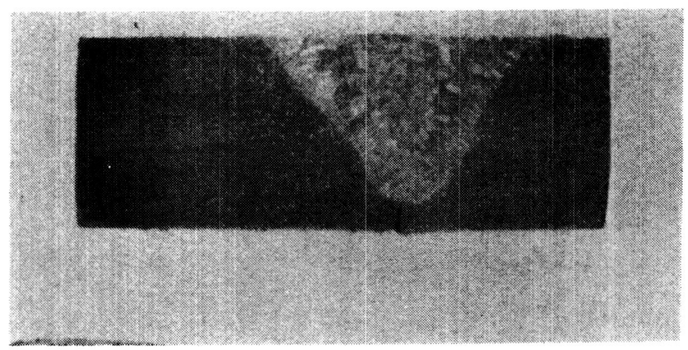
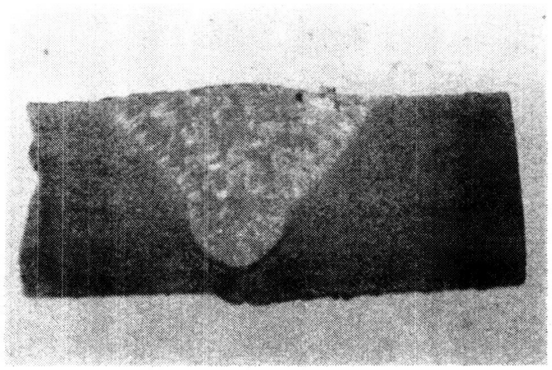
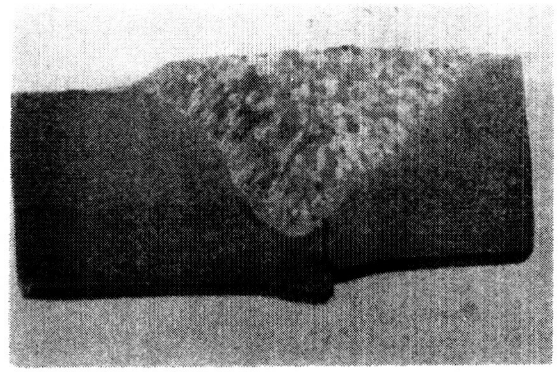


(d)

Fig. 4 Cross-Sectional Weldments



(e)



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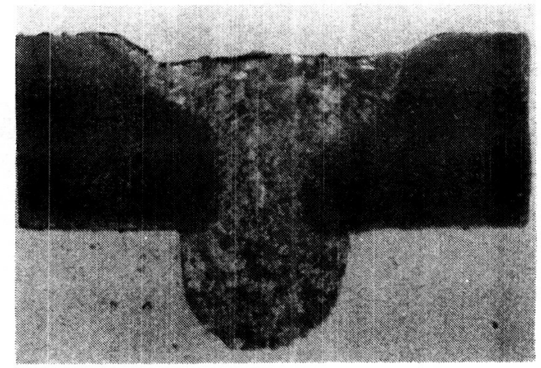

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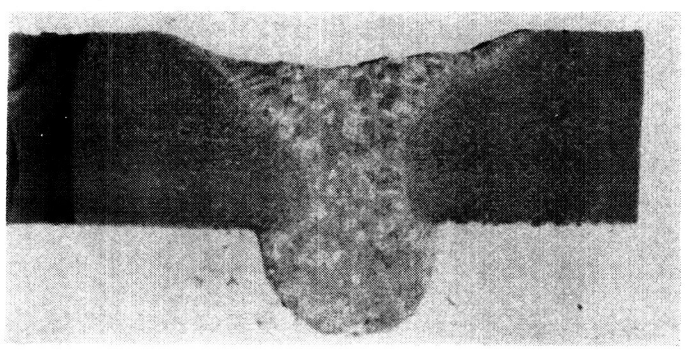

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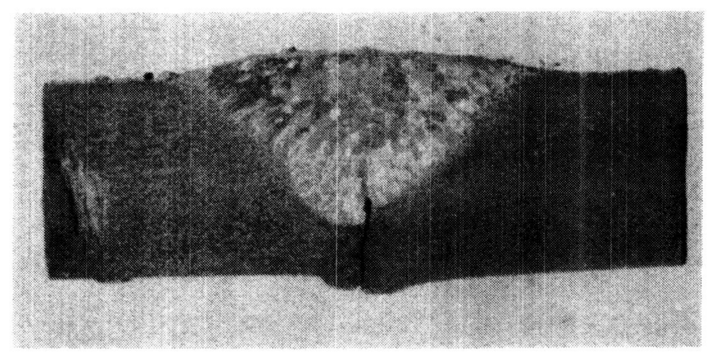

(i)

Fig. 4 (Cont.) <u>Cross-Sectional Weldments</u>

Table 2

DESCRIPTION OF CROSS SECTION WELDMENT PICTURES

Figure Number	Plotted Point Number	Torch Travel Speed, (in./min)	Wire Feed Rate (in./min)	Remarks
9	9	30	350	Wire Feed High
4(b)	10	20	267	Wire Feed Low
4(c)	11	20	292	Wire Feed High
4(d)	12	40	350	Wire Feed Low
4(e)	13	40	360	Wire Feed Low
4(f)	14	40	350	Wire Feed Low
4(g)	15	45	415	Wire Feed High
4(h)	16	35	318	Wire Feed High
4(i)	17	25	292	Wire Feed Low

to independently bring the carriage and the wire into the starting position. Both switches are then turned off. To start the welding operation, a hand-held master switch will actuate both electric clutches simultaneously. The circuitry diagrams are shown on Fig. 5 and 6.

VII. CONCLUSIONS AND RECOMMENDATIONS

The project was successful in demonstrating that wire feed and travel speed could be maintained in a preset relationship to each other over a range of speeds comparable to a given welding bead requirement. While a speed relationship, to give an approximately uniform bead over a wide range, was established under actual welding conditions, it was found that to obtain a completely satisfactory weld bead, other minor adjustments were necessary. The additional parameter found to be of primary importance was the power source voltage. Minor adjustments in voltage output were required to maintain uniform arc penetration characteristics as the current changed as a result of an adjustment in the wire feed rate and travel speed rate. These voltage adjustments were quite small in magnitude, usually on the order of $\pm$ 1/2 volt from the initial setting. However, without these minor adjustments satisfactory welding was not obtained. Thus to design a truly "one-parameter" control device, the factors included must control machine voltage in addition to the present wire feed and travel speed rates. Also it is quite likely that, having incorporated this third parameter, additional adjustments might still be necessary to account for such minor variations in arc materials as wire, base plate, or inert gas.

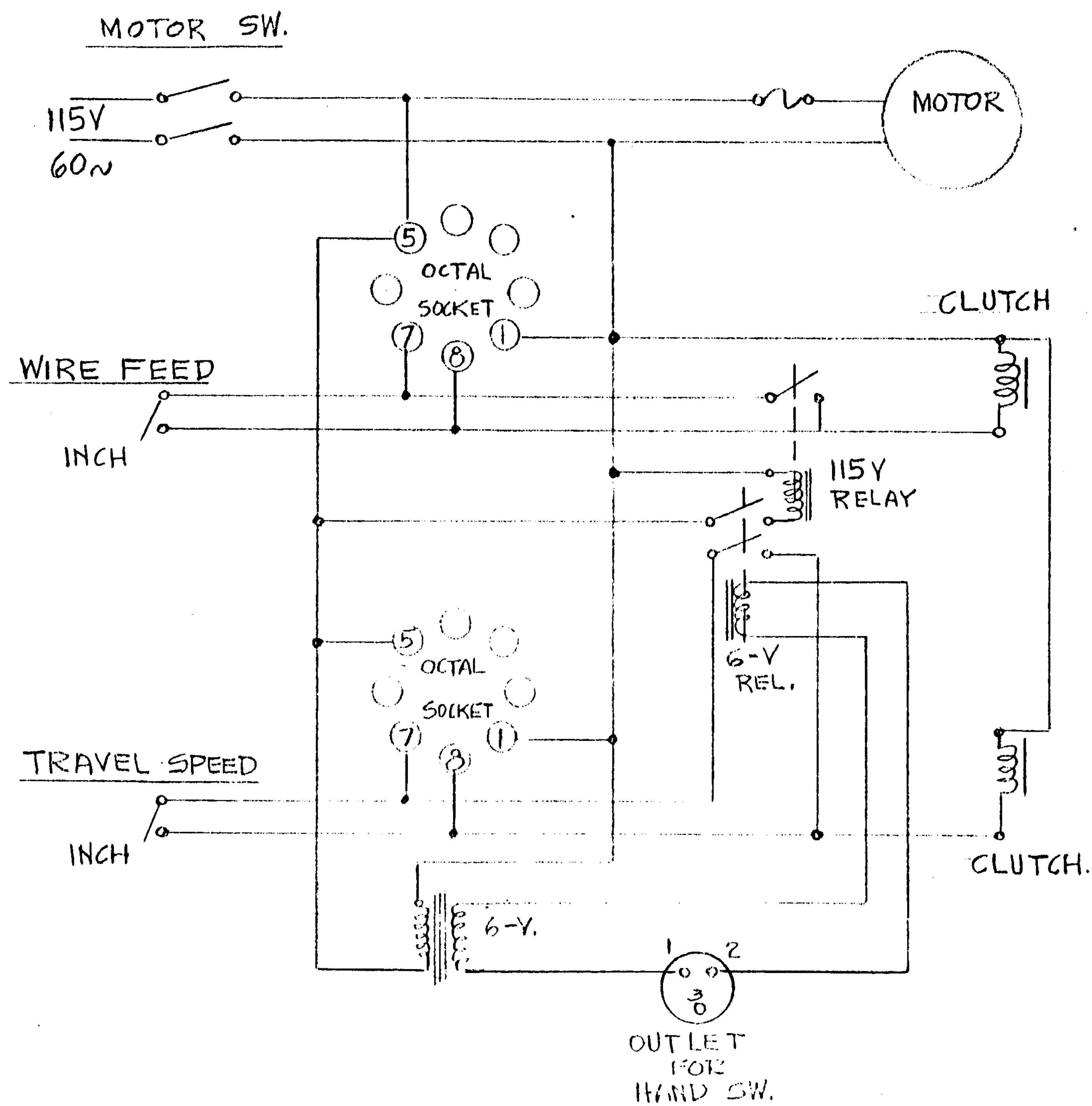

Fig. 5 Control Circuit for Travel Speed and Delayed Wire Feed Drives

ELEMENTARY DIAGRAM

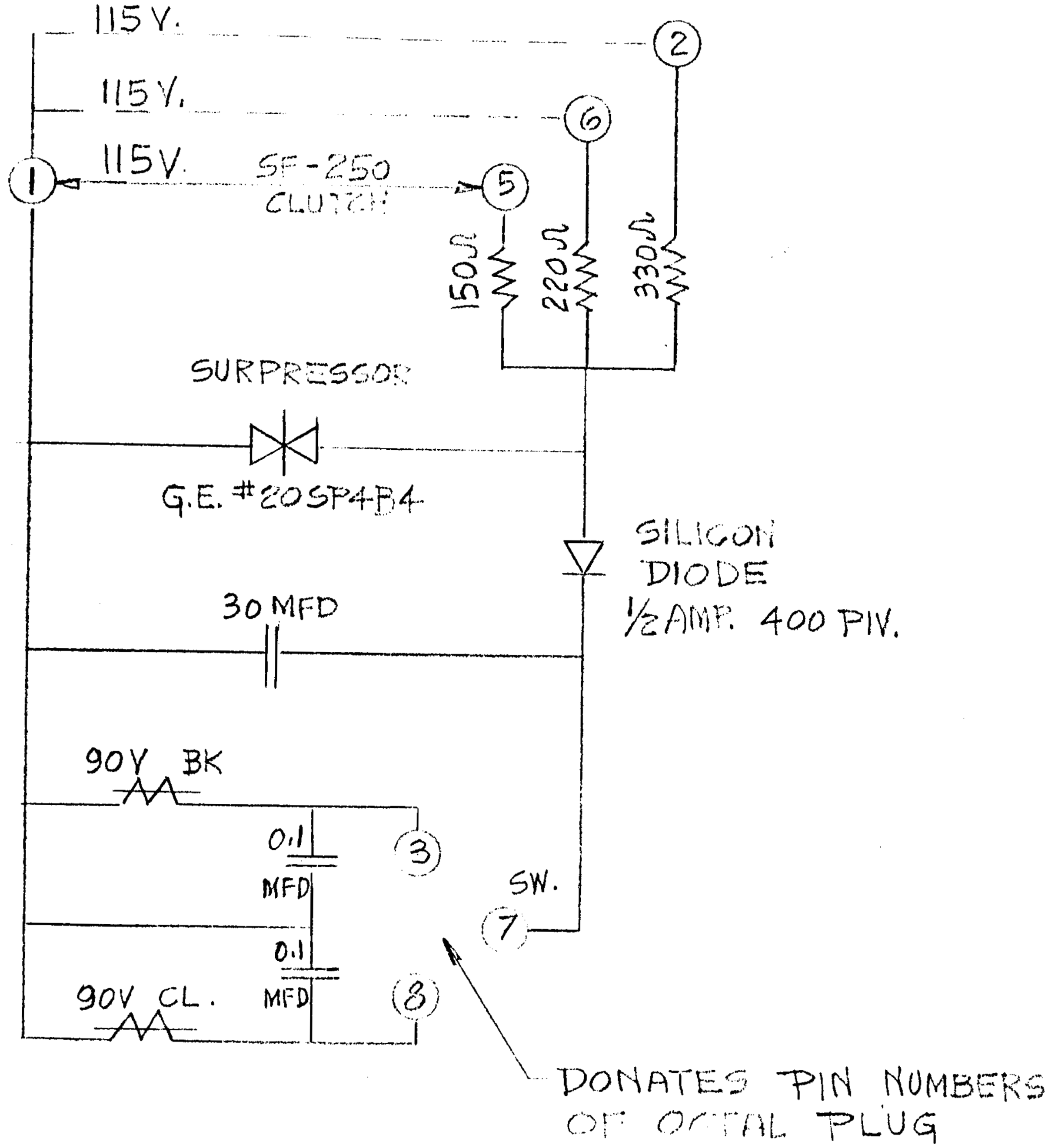

Fig. 6 Clutch Control No. 5400-278-024
(Warner Electric Brake and Clutch Comp.)